VISIT…

and the intangible use factors will favor one design over the other, particularly if the economics are made the final basis for choice. The final design is made and tested for performance and sent to production with suitable quality control tests indicated.

The process of design for static loads involves a great deal more than the mechanical operation of the stress-strain data to determine the performance of a section. The results obtained from the stress analysis are used to determine the functionality of the product and then, combined with the other factors involved to decide on a suitable design.

Prototype

Different tests are used on prototypes. As an example industry has a test where a load may be double that of a heavy person. Its two rear legs are positioned in front of an anchored board. The top of the chair has a rope or chain extending backwards to an oscillating device. The top of the chair will be pulled back to the point of almost failing backward and then released. The loaded chair will bounce on its two front legs. This cycle is repeated thousands of times. The industry test has requirements so if the chair is to be used in commercial environment its number of cycles will be many more than a noncommercial chair.

Using the approach suggested, designers can be guided in the design of static structure for performance in any environment from space, to aircraft, to land applications, to subsea use. Defining the requirements and using the data available or generated for the application, the end result can be made predictable to a sufficient extent that successful products result with minimum cost.

Automobile

For today's and tomorrow's transportation vehicles (automobiles, trucks, motorcycles, boats, airplanes, etc.) plastics offer a wide variety of benefits. Plastics play a very important role in these vital areas of transportation technology by providing special design considerations, process freedom, novel opportunities, economy, aesthetics, durability, corrosion resistance, lightweight, fuel savings, recyclability, safety, and so on (14, 153, 179, 234). Designs include lightweight and low cost principally injection molded thermoplastic car body to totally eliminate metal structure to support the body panels (Figs. 1-13 and 4-7). Example include pick-up trucks that use 100 lb thermoformed cargo-bed liners or RP boxes, RP bus interiors and bodies, injection molded TP fenders, etc. With more fuel-efficiency regulation new developments in lightweight vehicles is occurring with plastics. Plastics used include ABS, TPO, PC, PC/ABS, PP, PA, PVC, PVC/ABS, PUR, and RPs.

Different cars have and are being designed worldwide to produces low cost purchases, light weights, reduce fuel costs, reduce contaminating emissions, etc. Extensive use has been made by using unreinforced or reinforced TPs and/or TS plastics. A few of the many plastic products used follows. (1) Chrysler Corp.'s light-weight Composite Concept Vehicle (CCV) includes TP structural body panels with only a limited amount of metal underneath; it is an all-plastic body requiring a very large mold. (2) Ford Motor Co. has an all-aluminum body with plastic in some of the other parts. (3) GM focusing some plastics in their electric vehicle. (4) Asha/Taisun of Singapore producing taxi cabs for China with thermoformed body panels mounted on a tubular stainless steel space frame. (5) NA Bus Industries of Phoenix is delivering buses in USA and Europe with all RP bodies. (6) Brunswick Tech. Inc. of Brunswick, ME produces 30 ft RP buses except for the metallic engine (209).

There is Europe's plastic skin, 2-seat coupe, called the Smart car with molded-in color that virtually eliminates painting. The idea was to eliminate the need for three coats of paint and reducing both cost and emission problems, Project started in 1994 via a joint venture of Daimler-Benz in Stuttgart, Germany, then known as Mercedes-Benz, and the Swiss watchmaker SMH AG in Biel. They created a

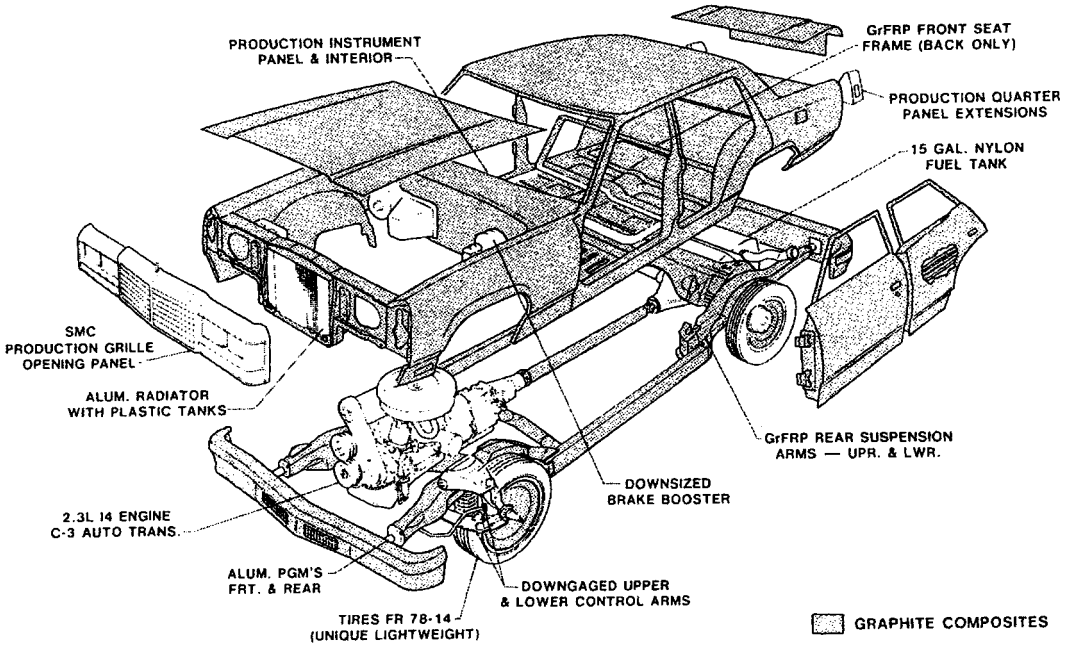

PRODUCTION INSTRUMENT PANEL & INTERIOR
GrFRP FRONT SEAT FRAME (BACK ONLY)
PRODUCTION QUARTER PANEL EXTENSIONS
15 GAL. NYLON FUEL TANK
SMC PRODUCTION GRILLE OPENING PANEL
ALUM. RADIATOR WITH PLASTIC TANKS
GrFRP REAR SUSPENSION ARMS — UPR. & LWR.
DOWNSIZED BRAKE BOOSTER
2.3L I4 ENGINE C-3 AUTO TRANS.
ALUM. PGM'S FRT. & REAR
DOWNGAGED UPPER & LOWER CONTROL ARMS
TIRES FR 78-14 (UNIQUE LIGHTWEIGHT)
GRAPHITE COMPOSITES

Fig. 4-7 Ford's lightweight concept vehicle made extensive use of high performance graphite fiber RPs.

new company called Micro Compact Car AG, or MCC. The first of the cars had plastic injection molded outer body panels using GE's PC/TP polyester blend (Xenoy). Its unitized TP body that tied together the front fender, outer door panels, front panels, rear valence panels, and wheel arch in one wrap-around package. The entire car weighs 1,440 lb (650 kg), about 600 lb (270 kg) less than most steel-body compacts.

World's First All-Plastic Car Body

From Sichuan Huatong Motors Group, Chengdu, China is the all-plastic car called Paradigm, a 4-door/5-passenger midsize vehicle. Its features include glass fiber-TS polyester RP sandwich chassis, thermoformed coextruded ABS body panels with molded-in color, adhesively bonded body, and, for the high-end model, a coextruded acrylic (ASA) cap cover providing high gloss. Automotive Design & Composites Ltd., San Antonio, TX, USA has served as the primary contractor for developing the concept. Chassis features a single thermoformed lower tub and an upper skeleton X-brace roof. It employs a monocoque structure where body panels are stitched-bonded to the chassis, forming a unitized structure.

Thermoformed chassis and body panels are featured on the car. The products were made initially in the USA for assembly in China. The car will weigh less than 2000 1b (900 kg). Automotive Design & Composites, Inc of San Antonio, TX, designed the vehicle to have body panels and trunk formed from coextruded sheet of ABS with an ASA cap layer that will hang on a pultruded composite frame. Ceramic tooling is used to thermoform plastic products.

The chassis is made from a 1/4 in. sheet of either ABS or TPO vacuum formed into a tub and reinforced with reinforced pultruded glass fiber-TS polyester plastic tubing. The hood and other products are being made from a 20 mm thick sandwich of thermoformed PPO-alloy skins, glass fabric infused with thermosetting vinyl ester, and a urethane foam core. The bumper and front fascia is thermoformed from a polyolefin elastomer sheet with an UV-resistant cap layer of DuPont's Tediar PVF film. The dash and

inner console is thermoformed from soft vinyl over ABS.

Quadraxially oriented (four directional layer) glass fabric-TS vinyl ester polyester RP sheet panels with a foam core and gel coating are used. Most of the panels are 3 mm thick with molded-in rib structure supports. Body skins are bonded to the chassis with a double-stick acrylic tape developed by 3M Co. as well as mechanical fasteners. Unlike most steel designs, no B-pillar structural component between the front and rear doors is required thus providing more interior space and easy entry since doors open in opposite directions.

The bumper to bumper measures 4.6 m (15.18 ft); weighs 815 kg (1793 lb) that includes 1200 lb (550 kg) of plastics; has a gas/electric hybrid power system, air bags, neon tube tail-lamps, etc.; and gets 132 km (60 miles) per gallon of fuel. Huatong and the Chinese government have funded $100 million in this global project.

Evaluation was made on four prototype cars, and China's Huatong Motors expects to assemble 5000 units at its Sichuan plant in the first year. Once on the market, the product will be a moving example of the capability of plastics engineering that includes using principally thermoforming technology. The all-plastic car will be using joining techniques that have been used for more than a half of a century. Many examples where adhesives are used exist. A prime example where adhesive joints have been used since the 1950s is on military aircraft where joints are subjected to all types of environments as well as static and dynamic loads, fatigue loads, weather changes, and so on.

Aircraft

Since the 1940s extensive use is made externally and internally of light weight, durable, and high performance plastic in commercial and military aircraft. Included are unreinforced and reinforced plastics as well as specialty plastics such as anti-icing coating (Figs. 4-8 and 4-9). Different RP parts (wing fairings, floor beams, rudder, elevators, engine cowl, etc.) are used on the Boeing 777 (Fig. 4-10) (Appendix A: **PLASTICS DESIGN TOOLBOX**).

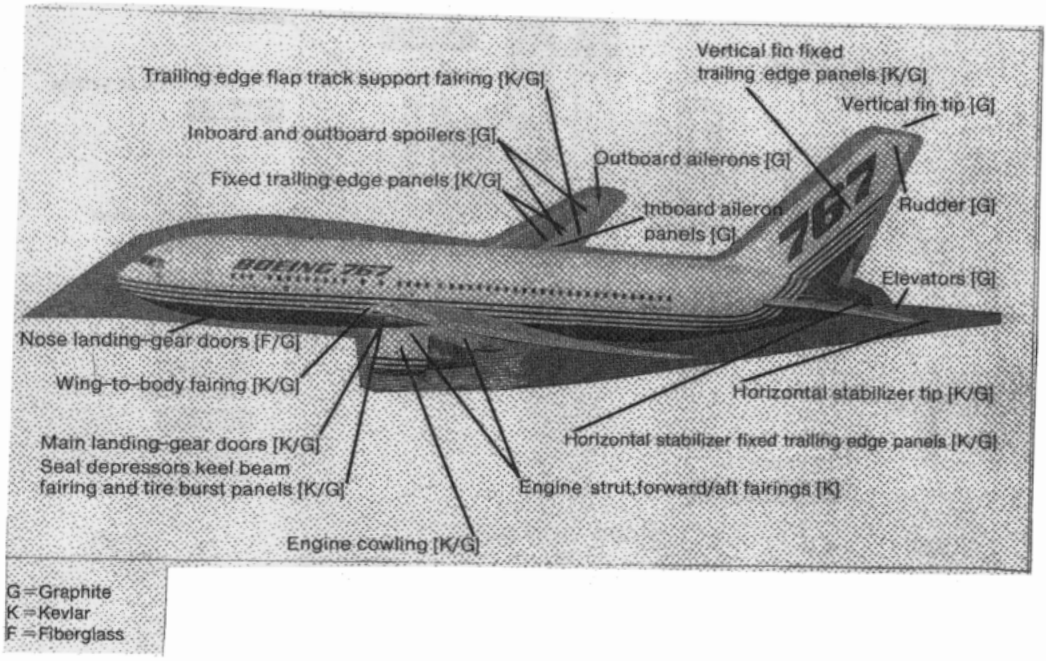

Trailing edge flap track support fairing [K/G]
Vertical fin fixed trailing edge panels [K/G]
Vertical fin tip [G]
Inboard and outboard spoilers [G]
Outboard ailerons [G]
Fixed trailing edge panels [K/G]
Inboard aileron panels [G]
Rudder [G]
767
BOEING 767
Elevators [G]
Nose landing-gear doors [F/G]
Wing-to-body fairing [K/G]
Horizontal stabilizer tip [K/G]
Main landing-gear doors [K/G]
Seal depressors keel beam fairing and tire burst panels [K/G]
Horizontal stabilizer fixed trailing edge panels [K/G]
Engine strut,forward/aft fairings [K]
Engine cowling [K/G]
G = Graphite
K = Kevlar
F = Fiberglass

Fig. 4-8 Extensive use is made of TP and TS plastics on the Boeing 767.

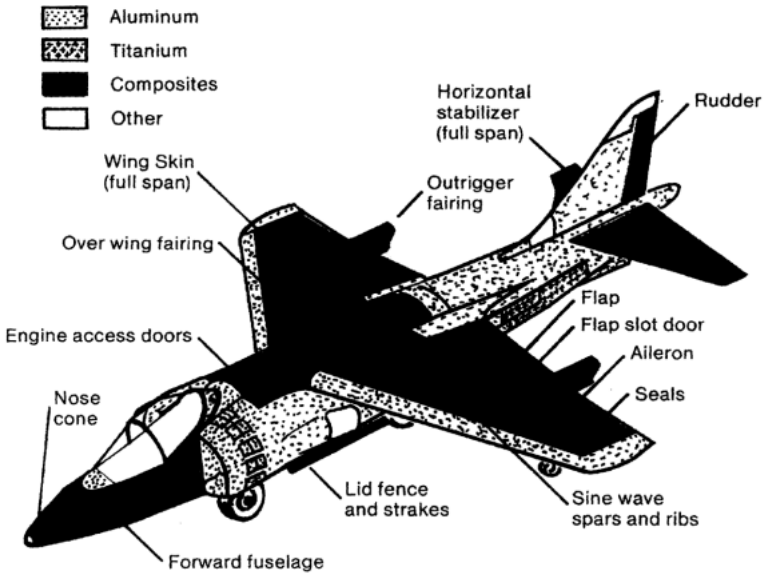


Fig. 4-9 Over 26% of this McDonald-Douglas AV-8B Harrier aircraft's weight uses carbon fiber-epoxy reinforced plastic; other plastics also used extensively.

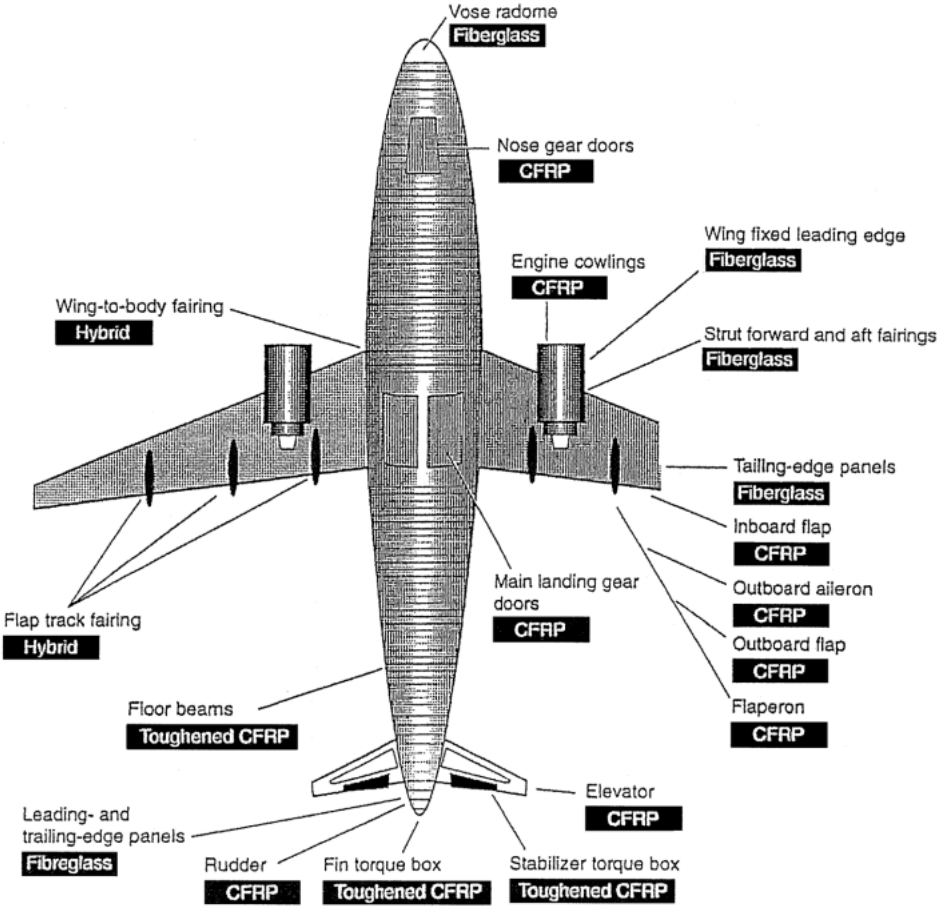
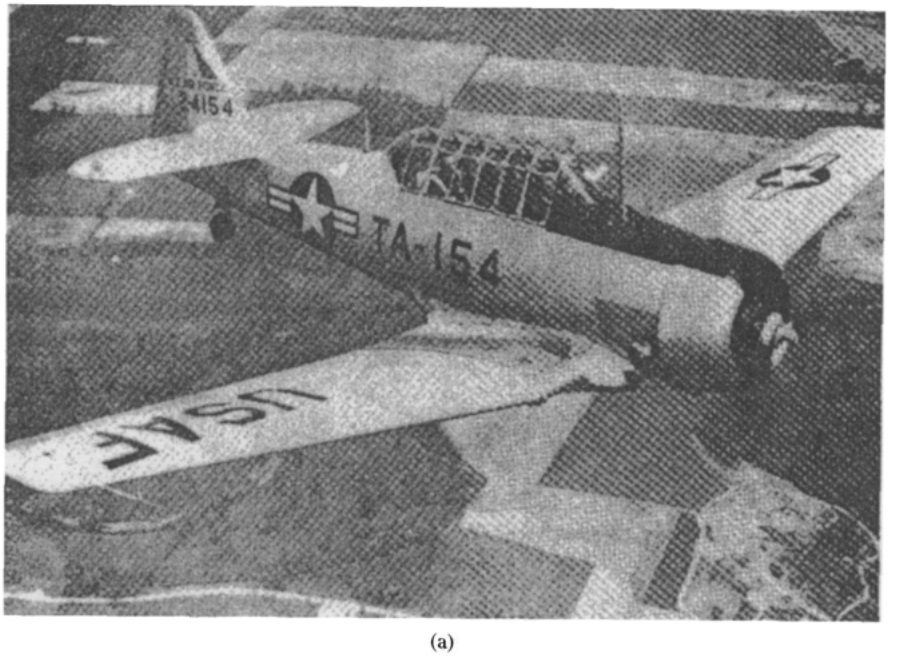
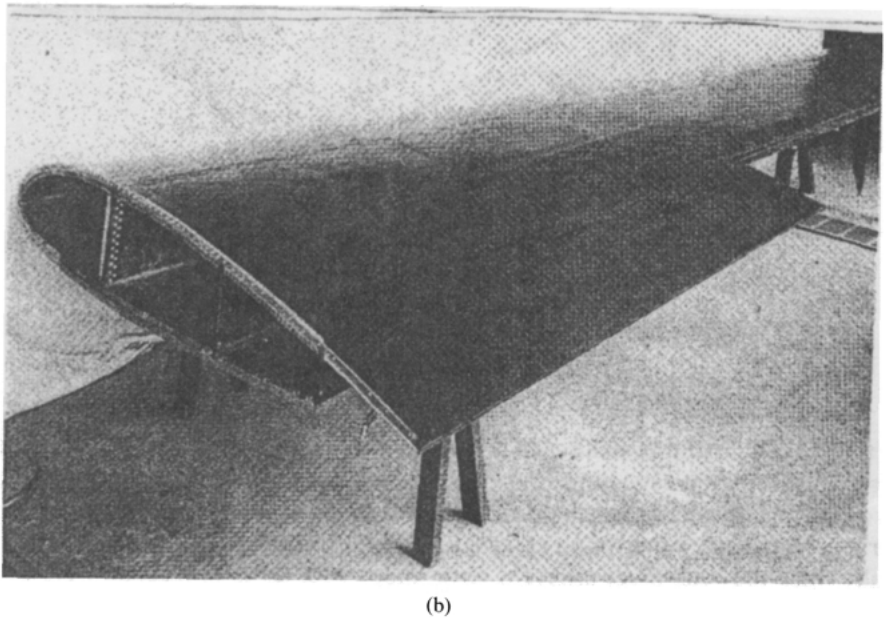


Fig. 4-10 RP products on the Boeing 777.

During 1944 at U.S. Air Force, Wright-Patterson AFB, Dayton, OH the first successful all plastic airplane (primary and secondary structures) was designed, fabricated, and flight tested (Fig. 4-11). It used glass fiber-TS polyester hand lay-up RP that included the use of the lost-wax process sandwich constructions for the monocoque fuselage, wings, vertical stabilizer, etc. (Chapter 8, **REINFORCED PLASTIC**).

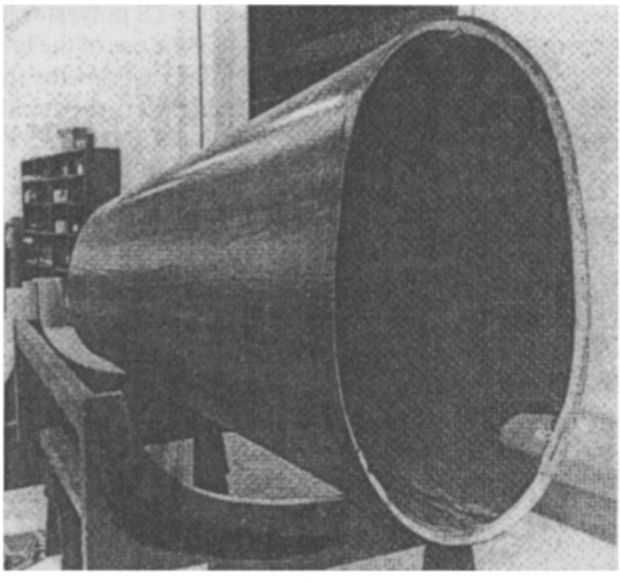


(a)

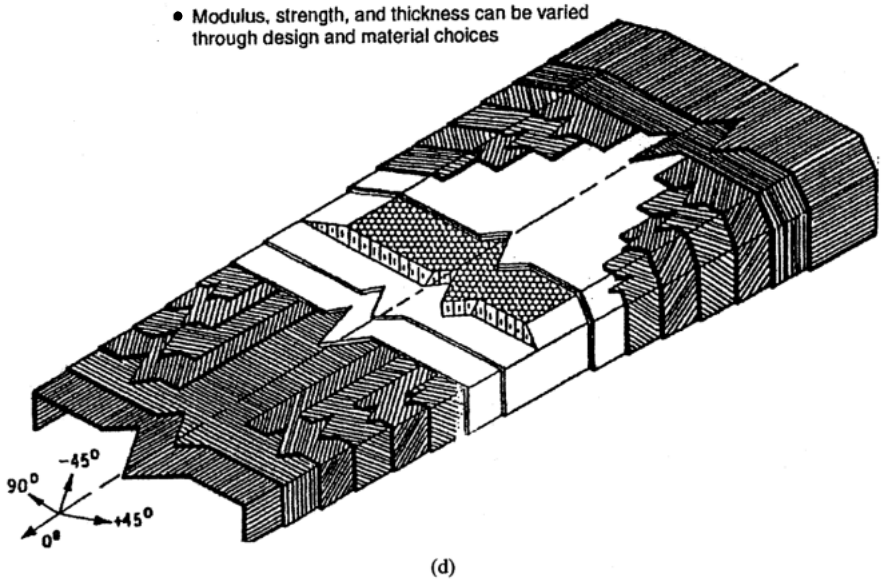


(b)

Fig. 4-11 (a) BT-15 in flight, (b) sandwich wing section using RP skins and cellular cellulose acetate foam, and (c) section of the monocoque fuselage, and (d) example of a design flexibility in RP construction.



(c)



(d)

Fig. 4-11 (*Continued*)

Over the years innovations in aircraft have given rise to more new plastic developments and have kept the plastics industry profits at a higher level than any other major market principally since they can meet different environmental and load conditions. Virtually all plastics have received the benefit of the aircraft industry's uplifting influence. Practically all conceivable top quality plastics are used to provide cost advantages and improvements on flight system performance. At least 5% of commercial plane's weight is plastics. This percentage is expected to double or perhaps triple in the future. Military aircraft include those with up to at least 50 wt% of primary and secondary structures.

The chief challenge to the plastics industry is not in pounds of plastics needed but rather in the translation of plastic development technology into production line

know-how. The aircraft industry is geared to pay high prices for plastics with exceptional properties; as high as hundreds of dollars per pound with up to ten-fold cost increases for fabricated products plus additional dollars to conduct continual testing and evaluation to insure safety of aircraft operation.

Medical Product

Plastics continue to make inroads regarding medical applications. Certain plastics have been found to exist in the environment of living tissues. In addition to being of direct aid in medicine, they are also important in medical devices and packaging medical items.

In effect doctors are designers. They are constantly helping design, test and evolve new materials and equipment to augment new and proposed methods of treatment and surgery. Their long, intensive training as basic scientists uniquely suits them to the designer capacity.

Bioplastic

New plastic applications and plastics are continually in use to help in the field of medicine (also biological systems, etc.). They include both mechanical and chemical applications and show the makeup of the field that could be called bioplastics (186). The heart valve that is often used in surgery to correct heart deficiencies was a spectacular contribution to medicine. In order for it to be successful it required first, ingenuity in designing a product that would function as a replacement for the mitral valve and to perform as well as the one replaced long enough to justify the risk involved in the operation. Second, it also required using a material that would function in the highly complex environment of the human circulatory system without being degraded and without causing harm to the circulatory system.

The use of special elastomer plastics (polyurethanes, silicones, etc.) designed expressly for the purpose and tested for years to determine possible adverse in-vivo effects combined with good design resulted in a mechanical device that has been a major lifesaver (29). The role of the plastic designer in an area such as this is one of knowing material limitations, processing problems and of devising test procedures to monitor the performance of the product in the patient as well as in continuous laboratory testing.

Other surgical implants are essentially plastic repair products for worn out parts of the body. It is possible to conceive of major replacements of an entire organ such as a kidney or a heart by combining the plastic skills with tissue regeneration efforts that may extend life. This is used to time the heart action. Extensively used are plastic corrugated, fiber (silicone or TP polyester) braided aortas (24).

While it would be difficult to enumerate all of the efforts in the area of implants where plastics are involved, some of the significant ones are: (1) the implanted pacemaker, (2) the surgical prosthesis devices to replace lost limbs, (3) the use of plastic tubing to support damaged blood vessels, and (4) the work with the portable artificial kidney. The kidney application illustrates an area where more than the mechanical characteristics of the plastics are used. The kidney machine consists of large areas of a semi-permeable membrane, a cellulosic material in some machines, where the kidney toxins are removed from the body fluids by dialysis based on the semi-permeable characteristics of the plastic membrane. A number of other plastics are continually under study for use in this area, but the basic unit is a device to circulate the body fluid through the dialysis device to separate toxic substances from the blood. The mechanical aspects of the problem are minor but do involve supports for the large amount of membrane required.

Bioscience

There are two major areas of application for plastics in bioscience. The plastics make interesting materials to be used for